Revised Bulletin 70
New Bulletin 75

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Acknowledgments

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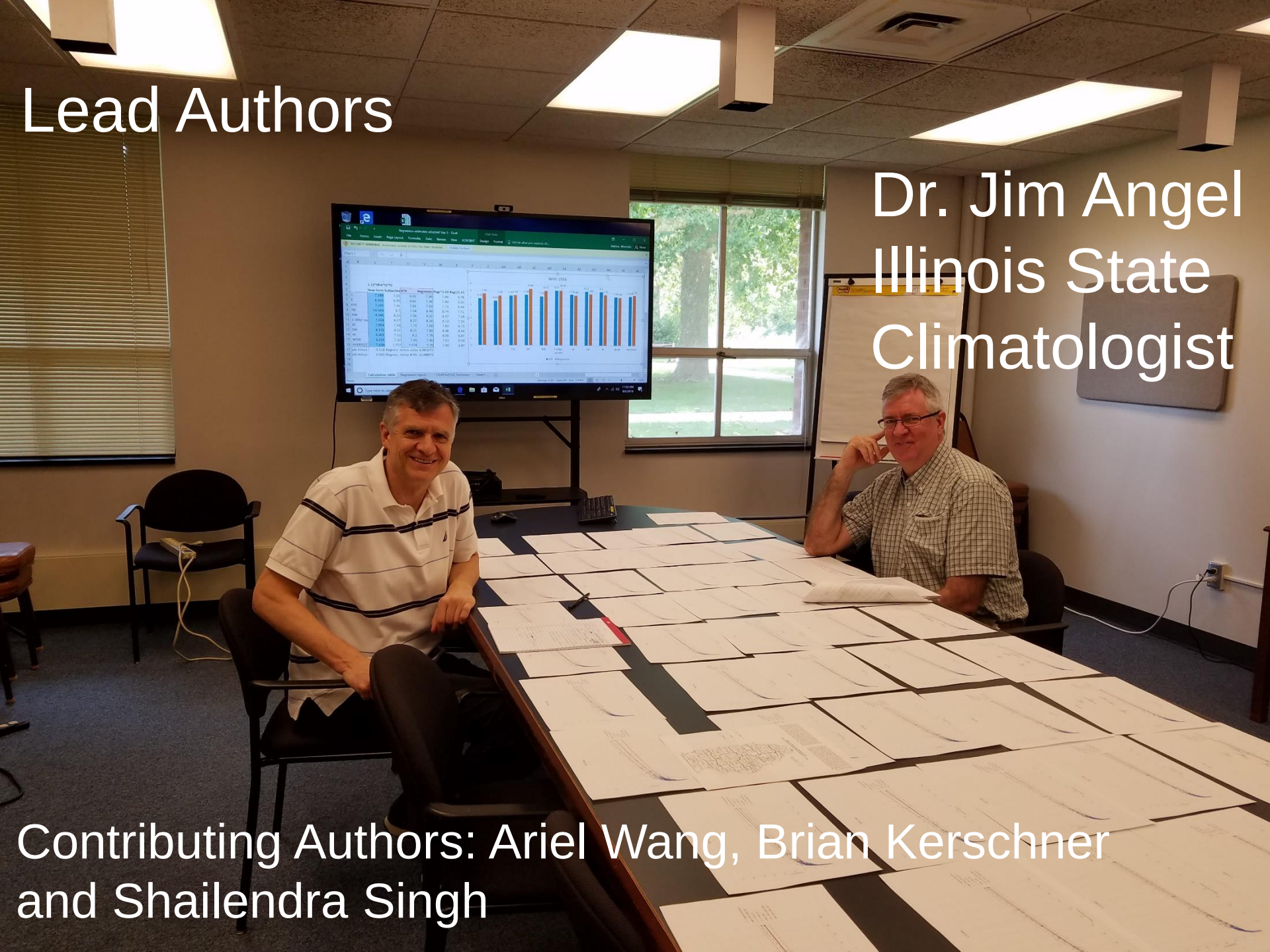
Coordinated with IDNR Office of Water Resources.

Lead Authors



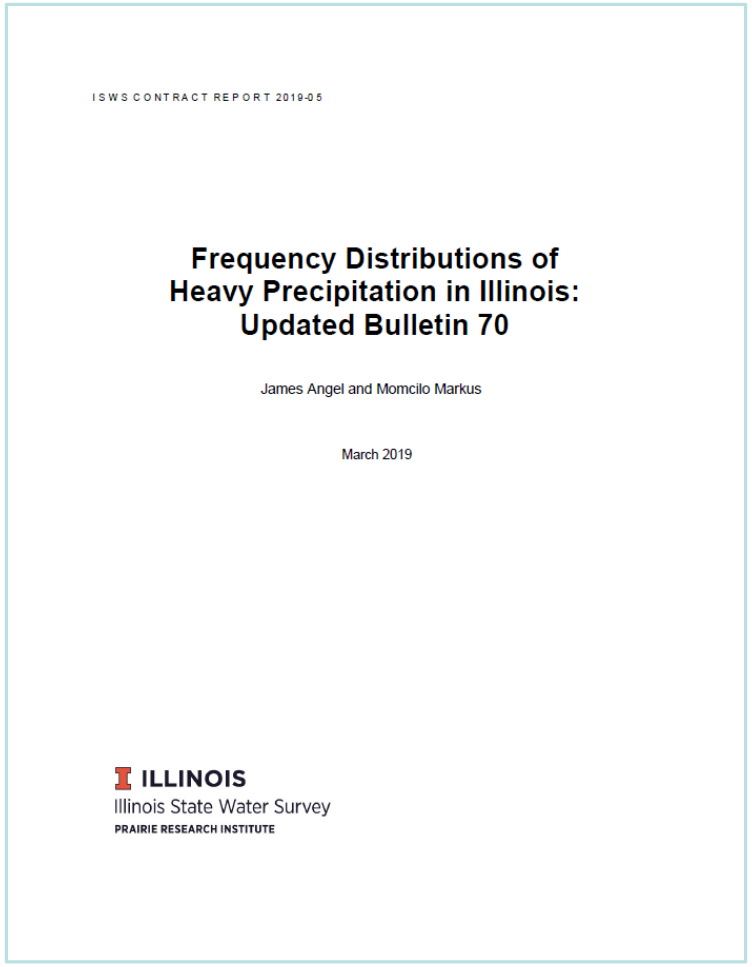
Dr. Jim Angel
Illinois State
Climatologist

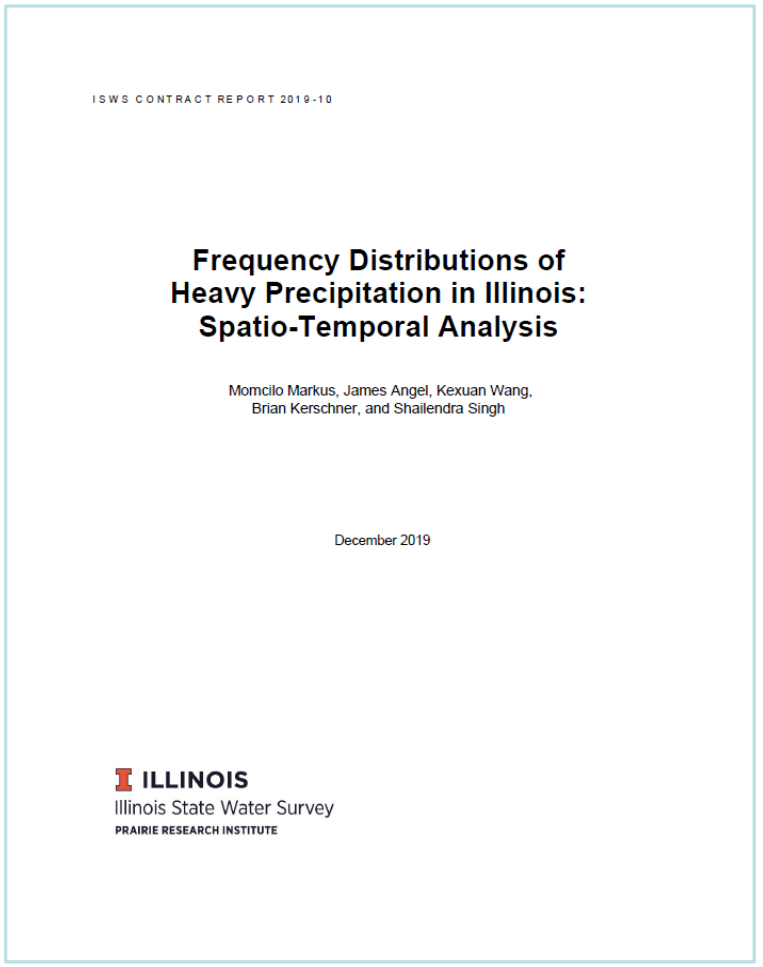
Contributing Authors: Ariel Wang, Brian Kerschner and Shailendra Singh

What is Bulletin 70?

- Report by Huff and Angel (1989) containing the expected rainfall amounts for selected storm durations and return periods (for example, the 24-hour, 100-year storm for a site in Illinois).
- Many state and local agencies in Illinois required the use of Bulletin 70 for design work after its publication in 1989.
- The original Bulletin 70 needed to be updated due to the observed increases in frequency and amounts of heavy rainfall events.

In 2019 ISWS published updated Bulletin 70 in two reports

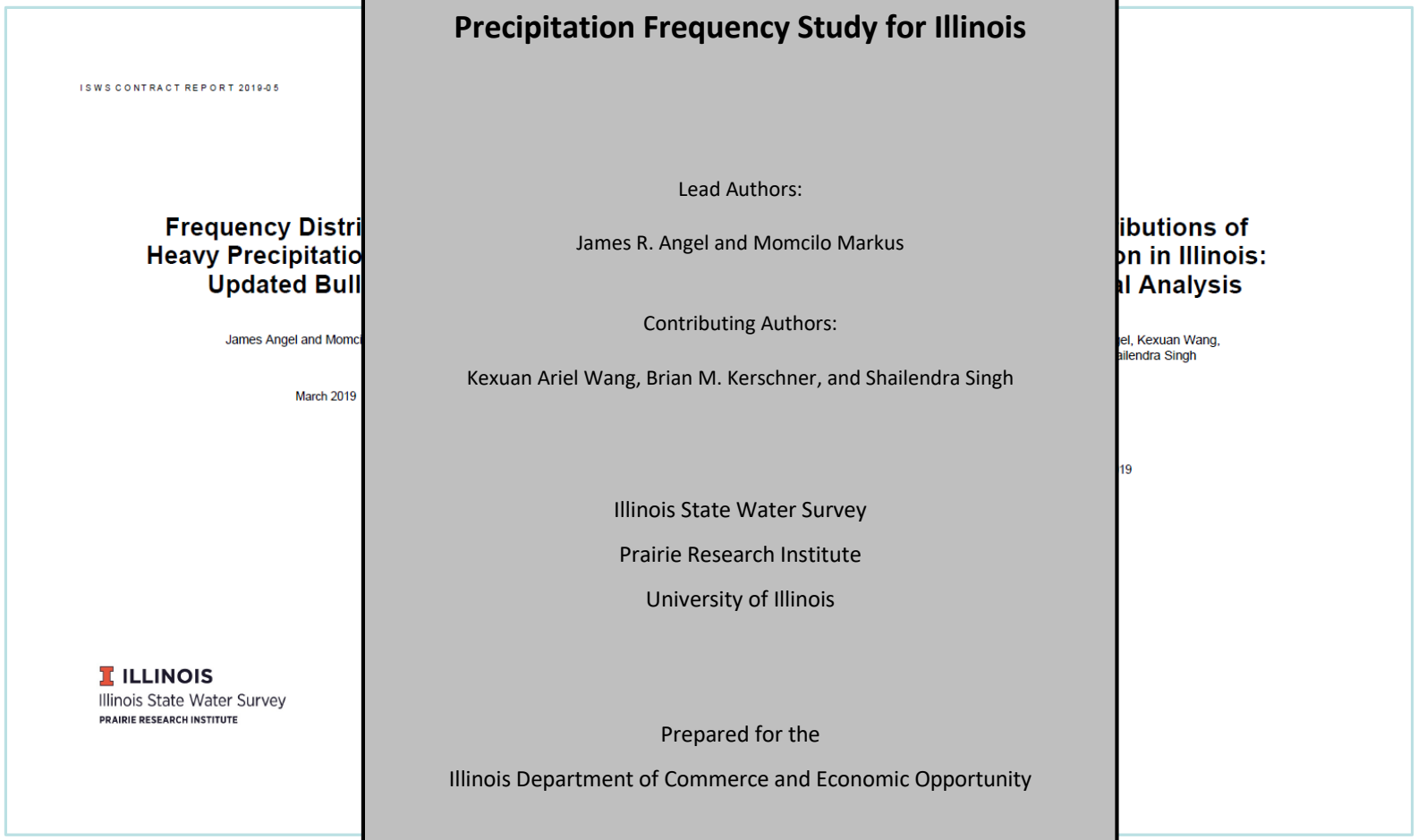




Angel, J. and M. Markus. 2019. *Frequency Distributions of Heavy Precipitation in Illinois: Updated Bulletin 70*. Illinois State Water Survey Contract Report 2019-05, Champaign, IL.

Markus M., J. Angel, K. Wang, B. Kerschner, and S. Singh. 2019. *Frequency Distributions of Heavy Precipitation in Illinois: Spatiotemporal Analyses*. Illinois State Water Survey Contract Report 2019-10, Champaign, IL.

“Updated Bulletin 70” = Bulletin 75



ISWS CONTRACT REPORT 2019-05

Frequency Distri
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March 2019

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Illinois State Water Survey
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ailendra Singh

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ISWS Bulletin 75

Precipitation Frequency Study for Illinois

Lead Authors:

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Contributing Authors:

Kexuan Ariel Wang, Brian M. Kerschner, and Shailendra Singh

Illinois State Water Survey

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University of Illinois

Prepared for the

Illinois Department of Commerce and Economic Opportunity

March 2020

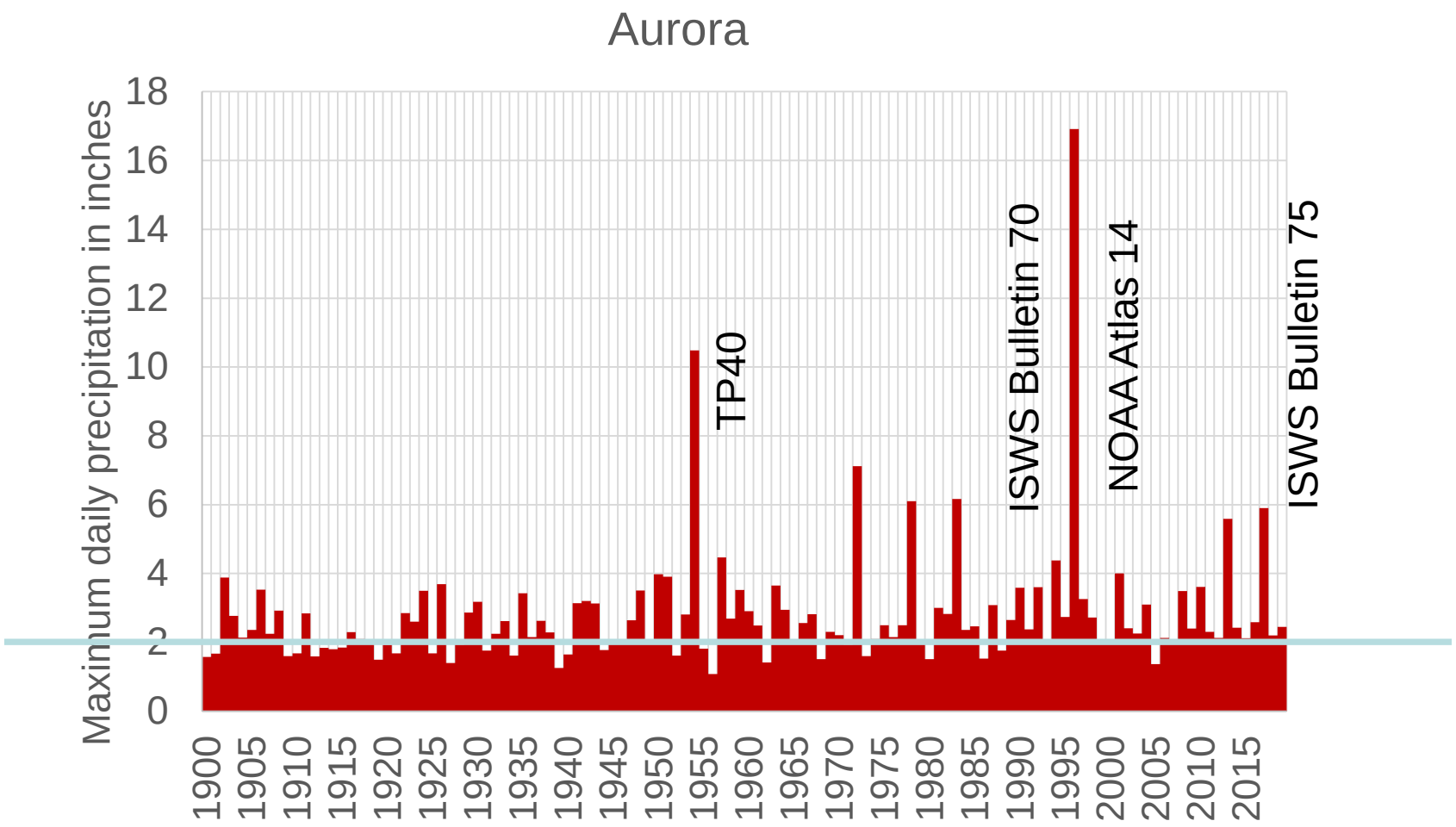
“Updated Bulletin 70”= Bulletin 75
(to be published in March 2020)

Historical evolution of rainfall frequency standards

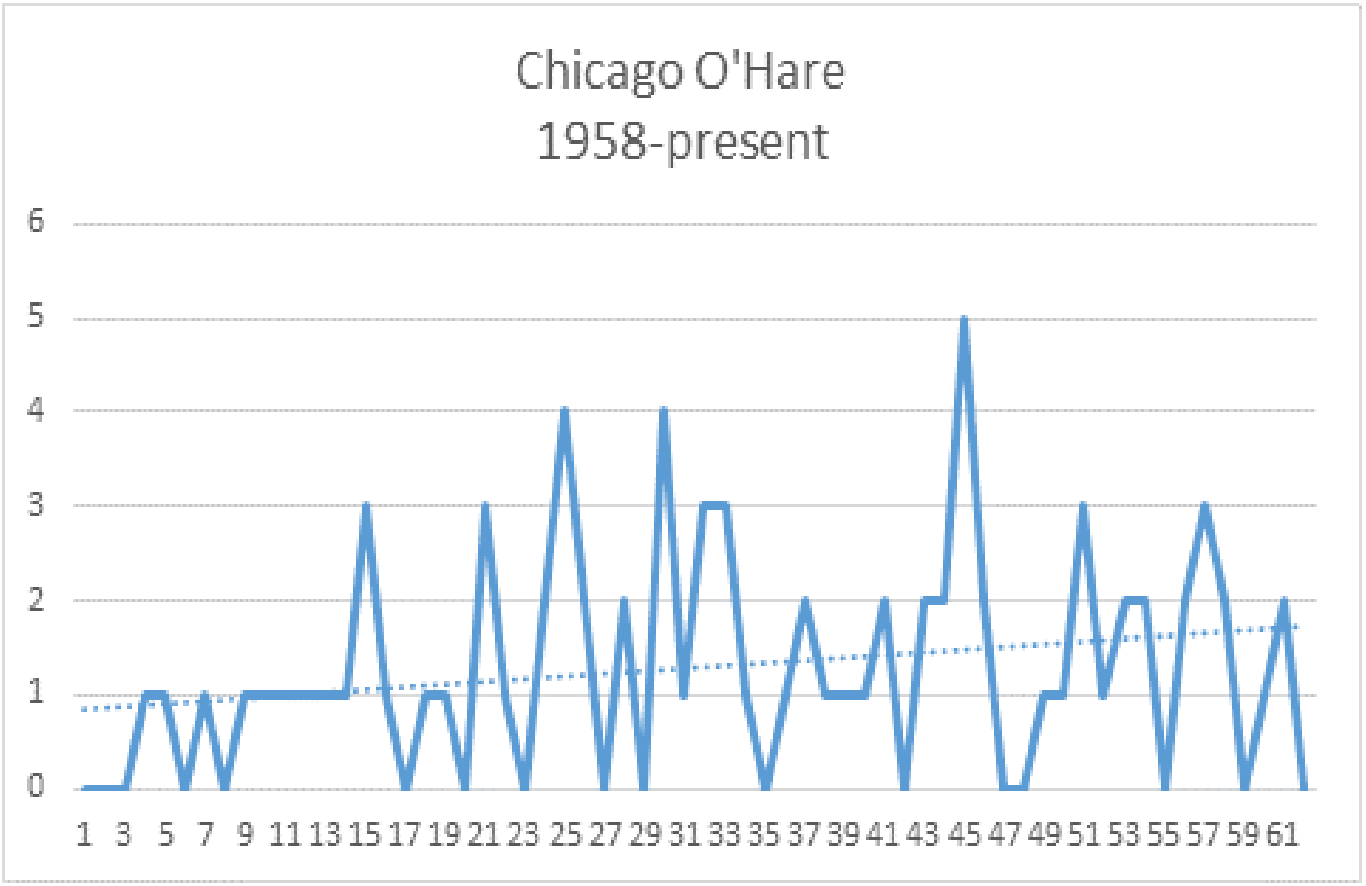
- TP-40 (Hershfield, 1961)
- Bulletin 70 (Huff and Angel, 1989)/*(Bulletin 71 (Huff and Angel, 1992)*
- NOAA Atlas 14 (Bonnin et al. 2004)
- Bulletin 75

Annual Maximum Daily Rainfall

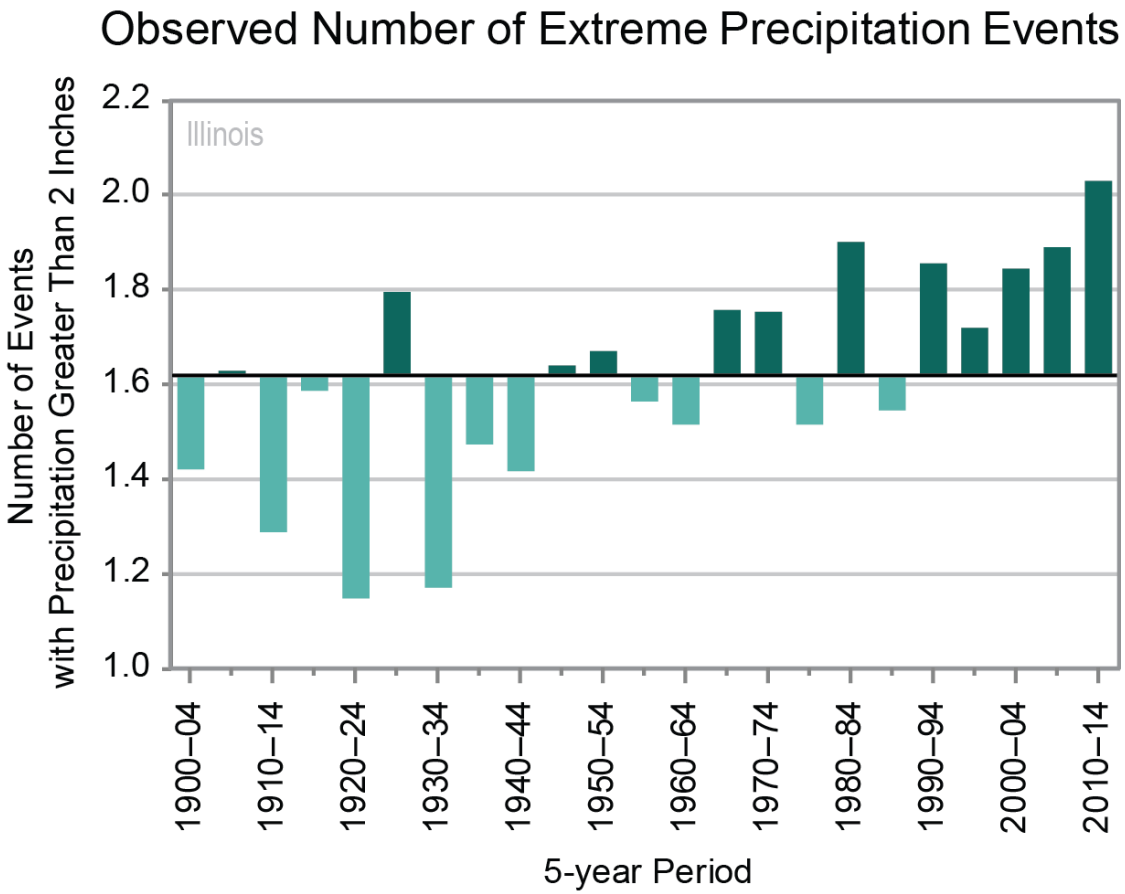
(none of the 10 largest values at Aurora were observed prior to 1950)



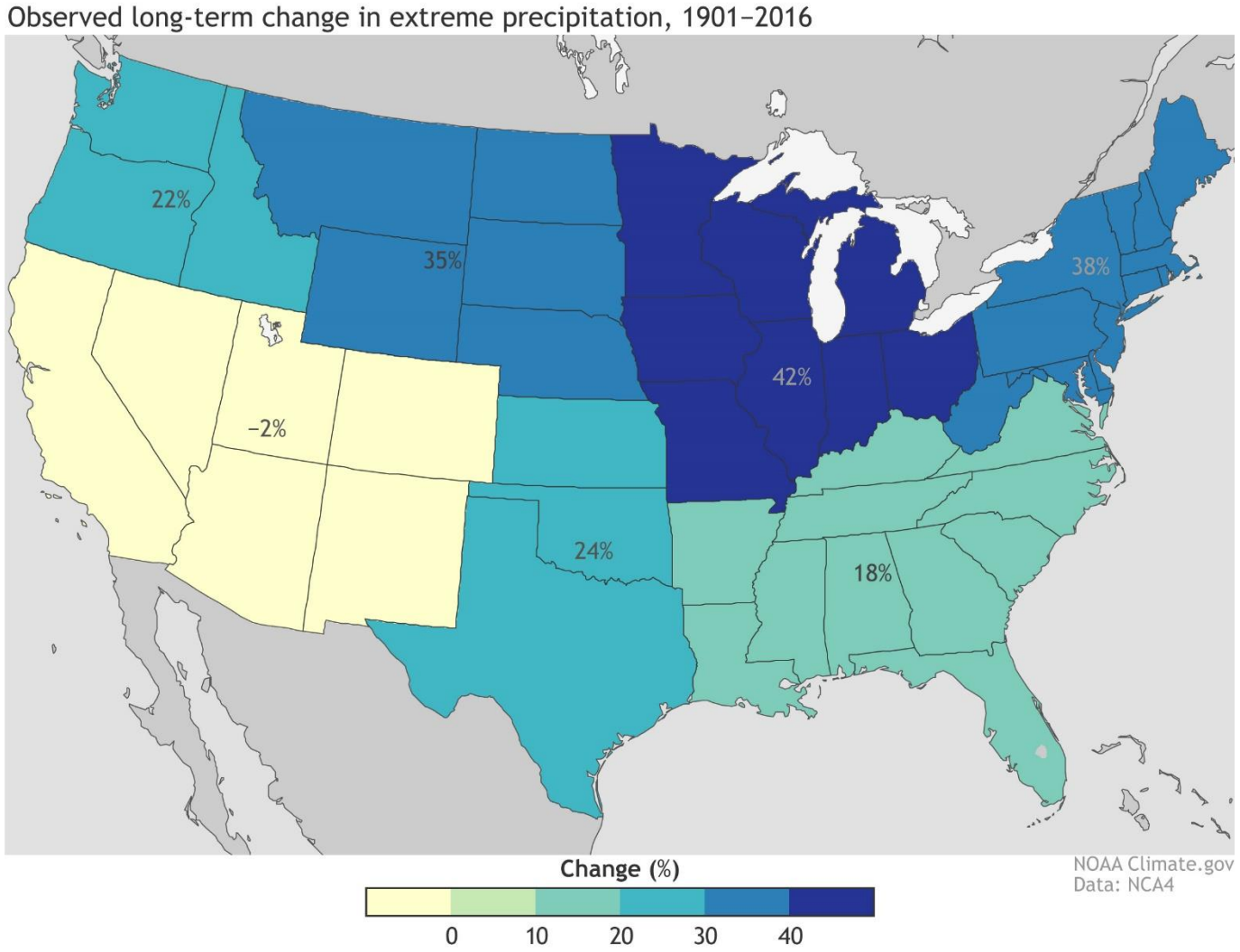
Observed trends in number of storms > 2 inches at Chicago O'Hare gage



Observed trends in frequency of heavy storms in Illinois



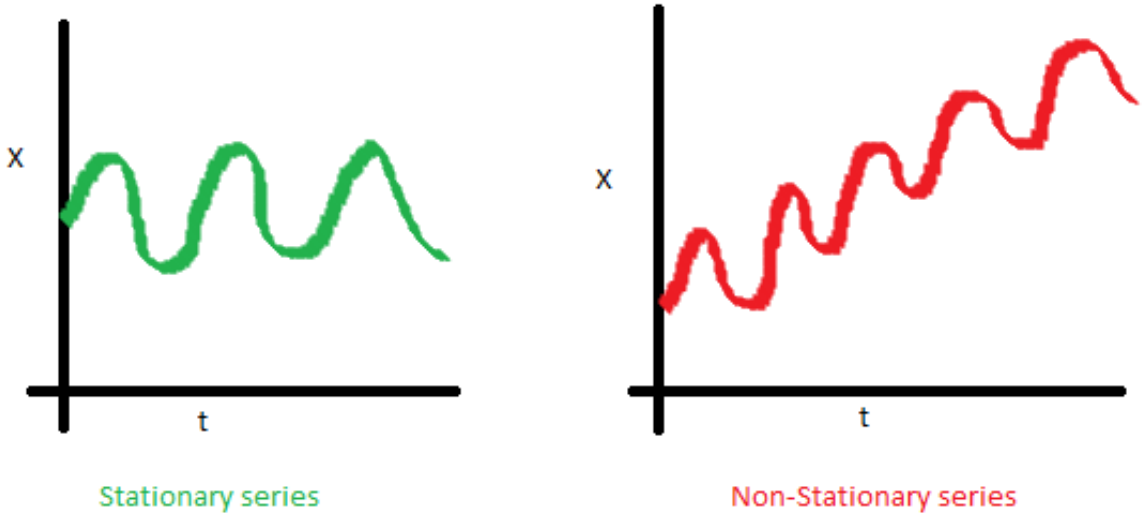
Change in the top 1% of extreme precipitation (the 99th percentile)



https://science2017.globalchange.gov/

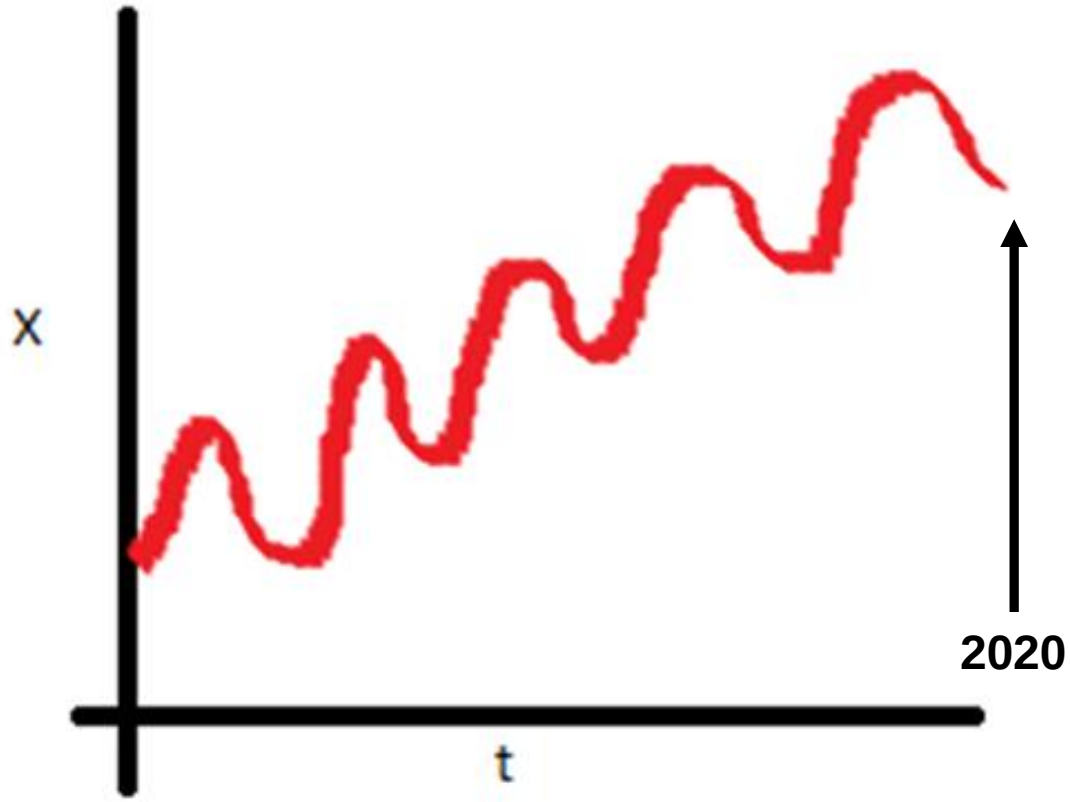
Stationarity of heavy rainfall

- Traditional assumption: Future variability will be like past variability. This assumption is called “stationarity.”



- In the light of climate change, assumption of stationarity may not be appropriate for precipitation frequency analysis.

Nonstationarity of heavy rainfall



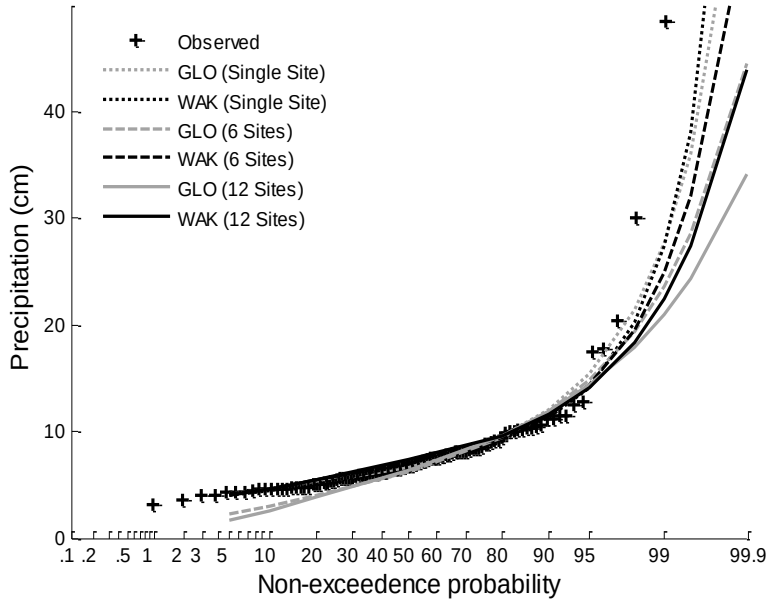
Non-Stationary series

Our Solution to Observed Changes

- Use 1948-2017 data to better represent the current, wetter climate
- Three times as many stations are available from 1948 onward
- Included a Bulletin 70 style adjustment to account for the increasing trend in heavy rainfall events

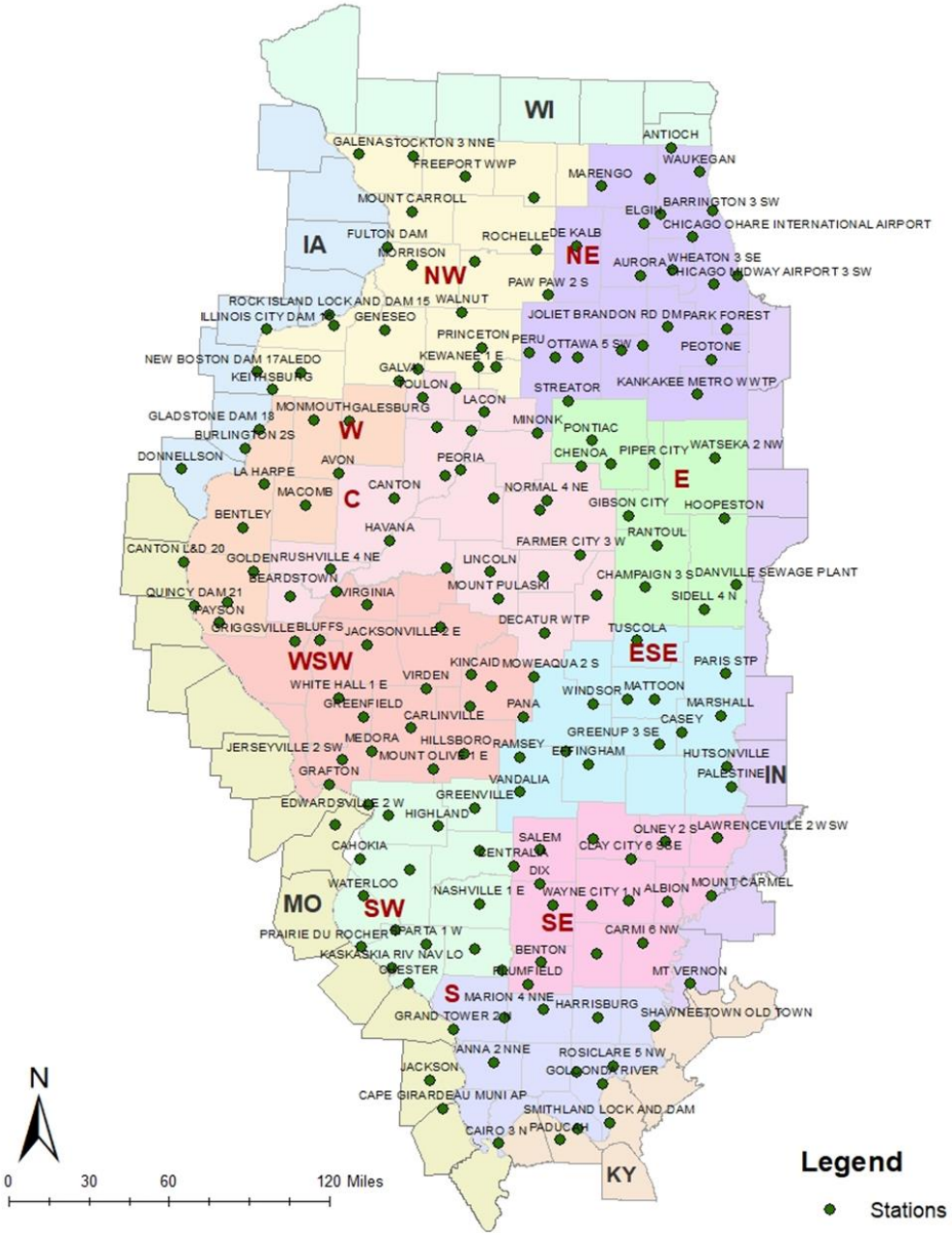
L-Moments Software

24-Hour Precipitation Annual Maximum Frequency Analysis Results for Aurora, IL.

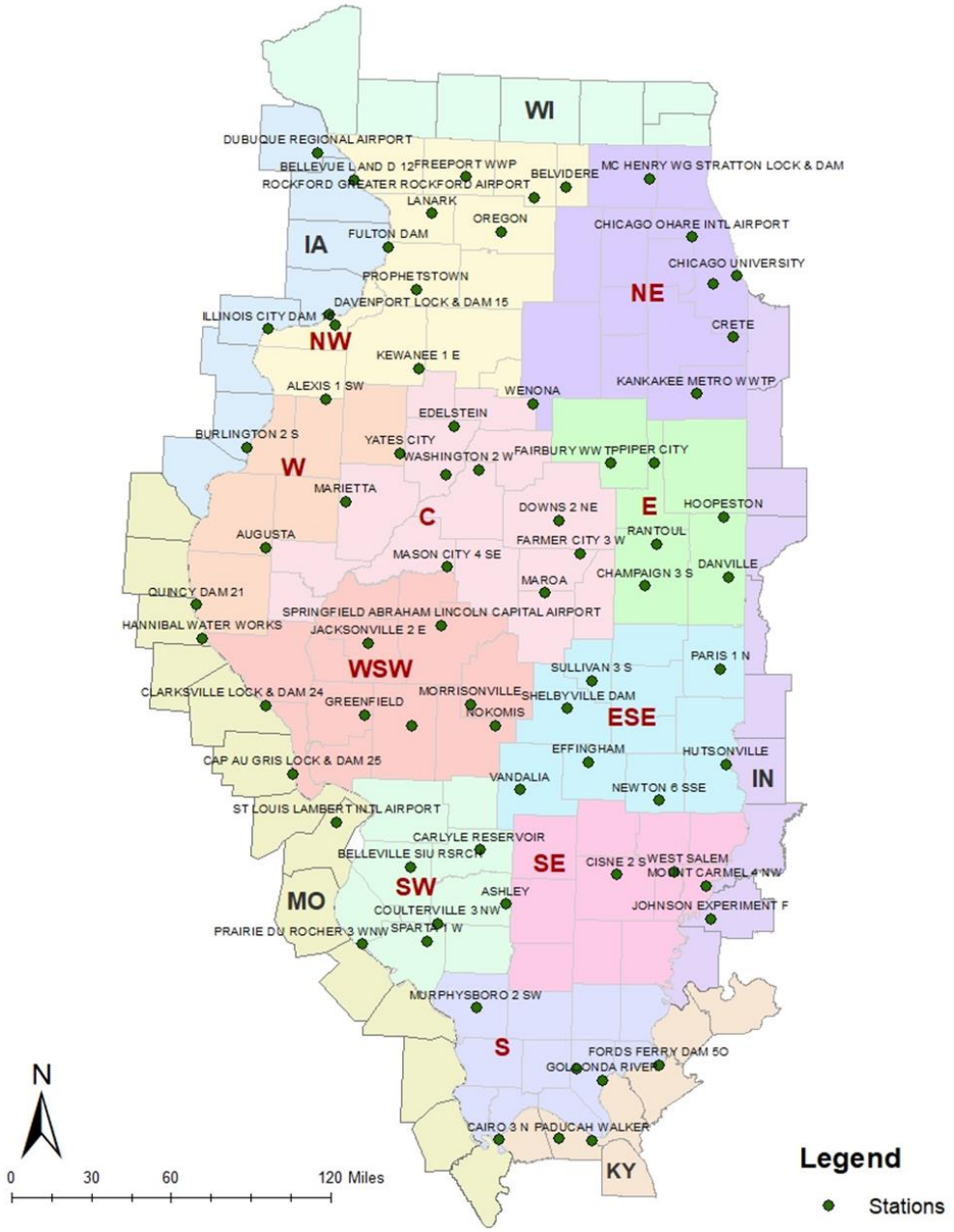


Markus, M., Angel, J.R., Yang, L. and Hejazi, M.I., 2007, Changing estimates of design precipitation in Northeastern Illinois: Comparison between different sources and sensitivity analysis, J. Hydrology, 347(1-2):211-222.

176 Daily Precipitation Stations 1948-2017



73 Hourly Precipitation Stations 1948-2017



Process

- Obtained and QC’d the data
- Selected stations based on availability and length of record
- Calculated the expected precipitation at selected return periods for 1 to 10 days using L-moments

Process

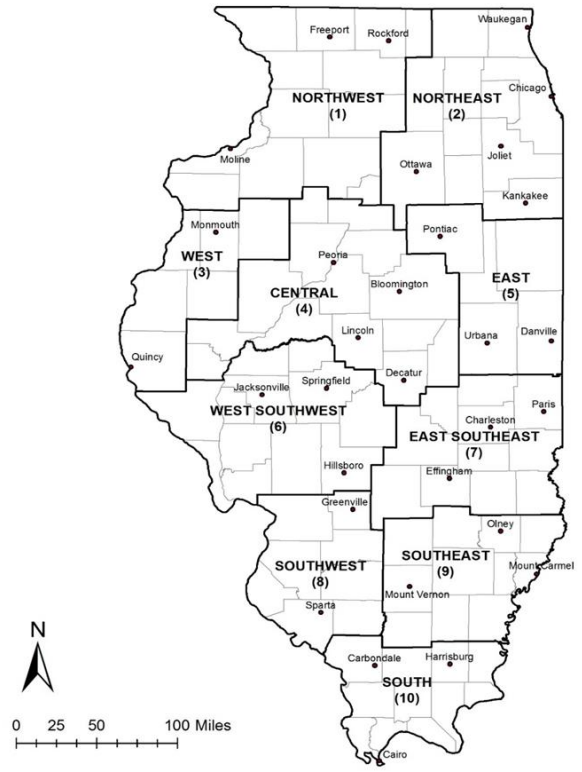
- Adjusted the results from the annual maximum series into a partial duration series using a standard approach (Langbein's equation (1949))
- Converted the constrained to unconstrained using standard conversions

Table 1 Conversion from Constrained to Unconstrained Precipitation Adopted in this Study

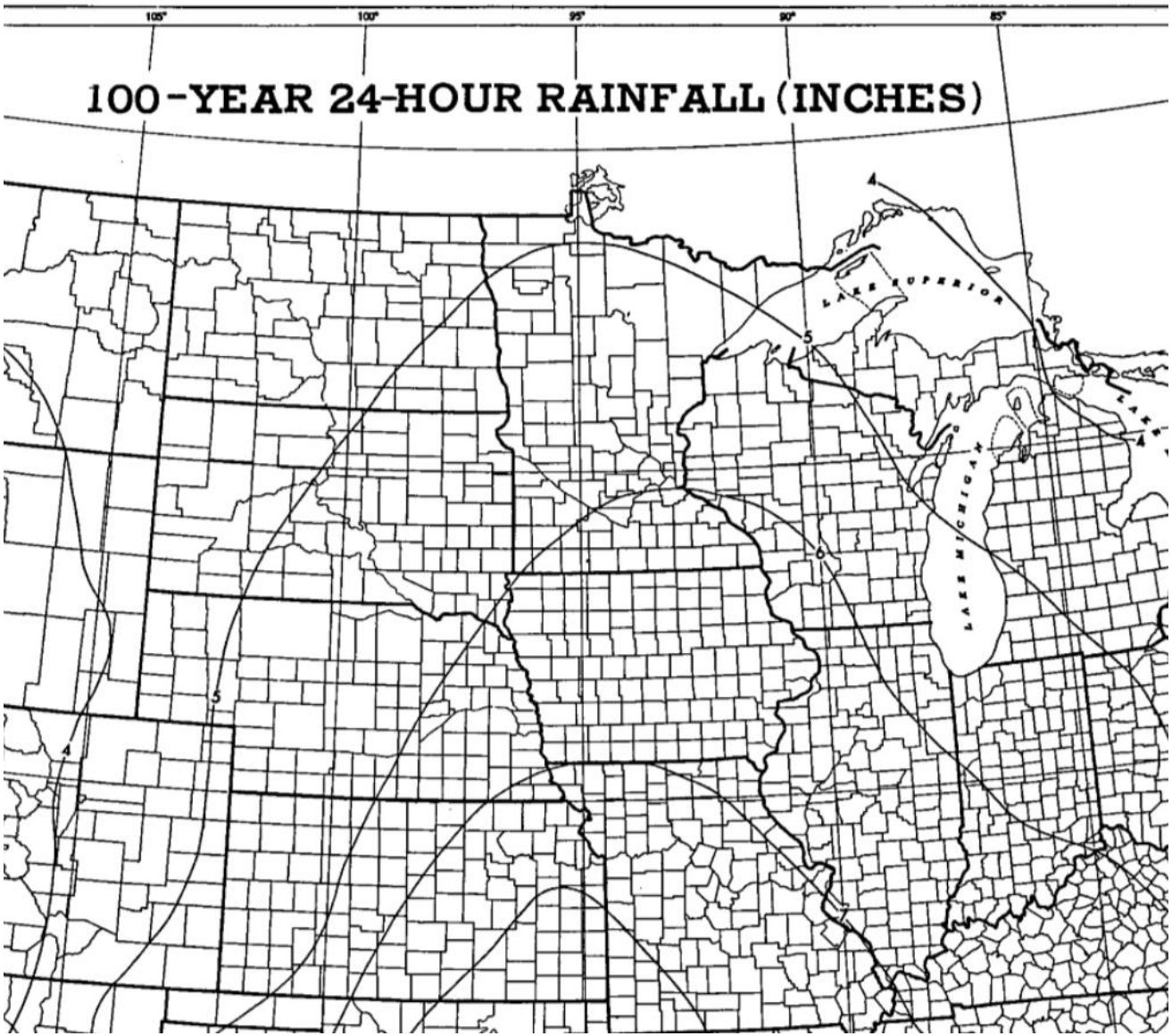
From	1 day	2 days	3 days	5 days	10 days
To	24 hours	48 hours	72 hours	120 hours	240 hours
Conversion factor	1.13	1.04	1.02	1.01	1.00

Process …

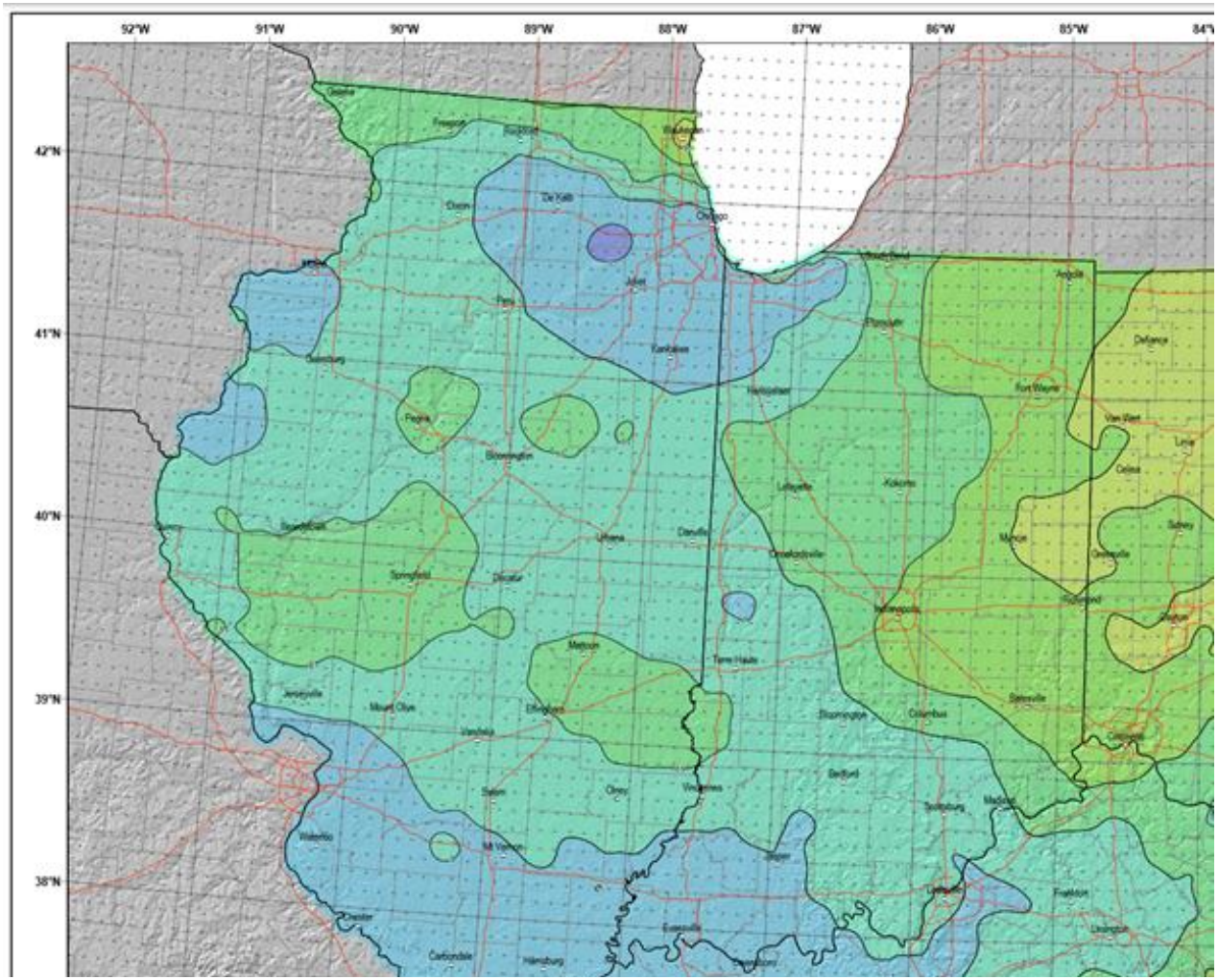
- Averaged the station frequency values into a regional frequency analysis (RFA)



TP-40 (Hershfield, 1961)



NOAA Atlas 14 (Bonnin et al. 2004)



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Isopluvials of 24 hour precipitation (inches) with Average Recurrence Interval of 100 years

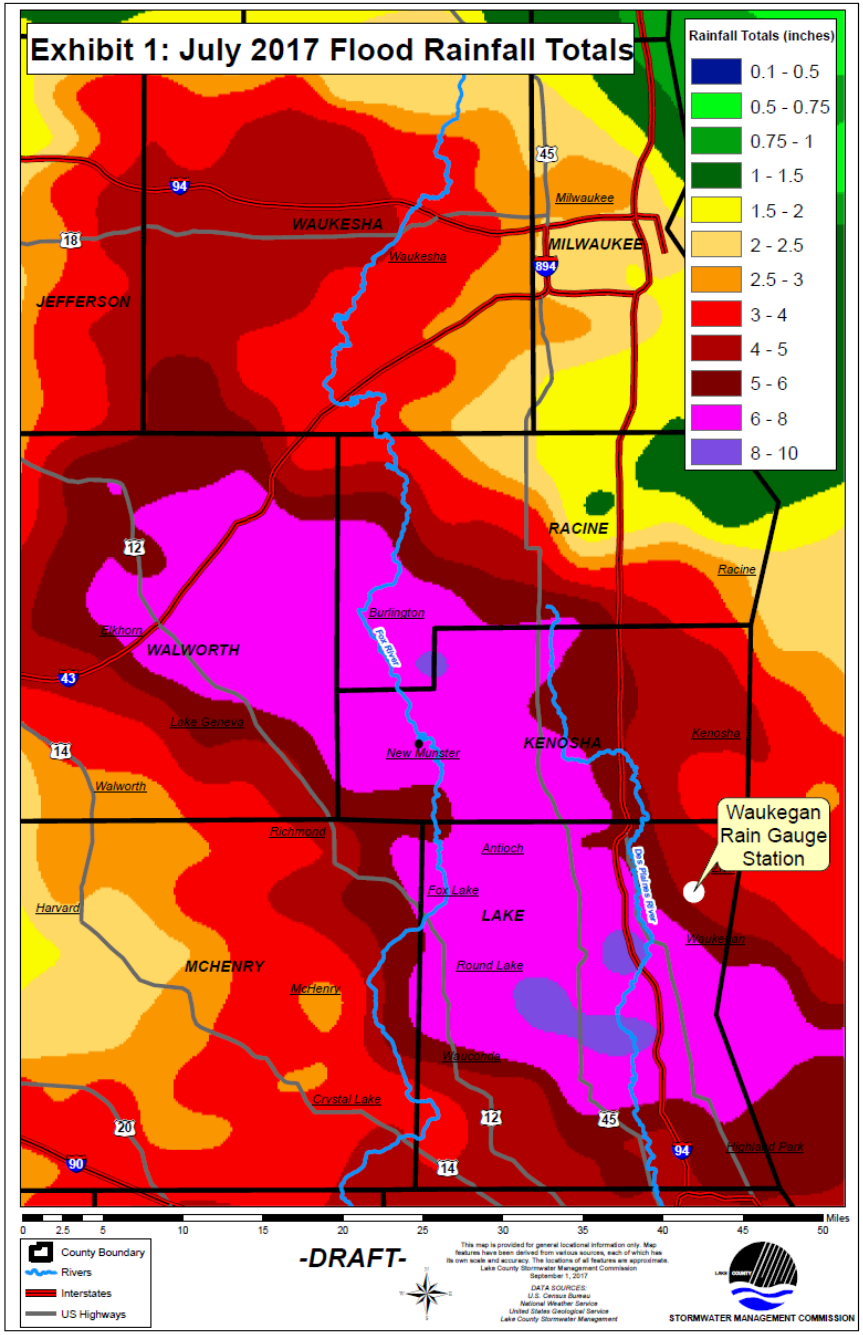
See NOAA Atlas 14 documentation for factors to convert to Annual Exceedance Probabilities for all estimates below 25 years

N

Inches

4.16 - 4.20	4.81 - 5.00	6.51 - 7.00	10.01 - 11.00
4.21 - 4.40	5.01 - 5.50	7.01 - 8.00	11.01 - 12.00
4.41 - 4.60	5.51 - 6.00	8.01 - 9.00	12.01 - 13.00
4.61 - 4.80	6.01 - 6.50	9.01 - 10.00	13.01 - 14.00

Projection: Lambert Conformal Conic; Datum NAD83; Standard Parallels: 38° and 45°; Central Meridian 83°



Courtesy of Kurt Woolford, LCSMC

Process

- Calculate frequencies for sub-daily durations using conversion factors due to limitations of hourly data

Table 2 X-hr:24-hr Ratios

Storm Duration (hours)	RFA 1948-2017	Bulletin 70	Atlas 14	Adopted
1	0.42	0.47	0.47	0.47
2	0.56	0.58	0.57	0.58
3	0.64	0.64	0.63	0.64
6	0.76	0.75	0.75	0.75
12	0.87	0.87	0.86	0.87
18	0.94	0.94	N/A	0.94

Ratios

2 months to 2 years	3 months to 2 years	4 months to 2 years	6 months to 2 years	9 months to 2 years	1 year to 2 years
0.470	0.538	0.590	0.672	0.762	0.830

Table 5.1. Ratios used to calculate sub-hourly frequency estimates based on the known hourly estimates, x-minute/1-hour

5-minute/1-hour	10-minute/1-hour	15-minute/1-hour	30-minute/1-hour
0.255	~~0.468~~ 0.447*	0.574	0.787

Table 5.2. Factors used to calculate frequency estimates for recurrence intervals less than 2 years based on the known estimates for 2 years recurrence interval.

* Matt O'Connor, P.E., HLR Engineers

Adjustment for Non-Stationarity

- Ratio of the 1983-2017 RFA divided by the 1948-1982 RFA

Table 3 Temporal Trend Adjustment Factors for 10 Sections

	Climatic section	24 hrs	48 hrs	72 hrs	120 hrs	240 hrs	Average
1	Northwest	1.07	1.07	1.03	1.05	1.12	1.07
2	Northeast	1.06	1.12	1.13	1.18	1.21	1.14
3	West	1.00	0.96	0.91	0.92	1.02	0.96
4	Central	1.02	0.94	0.94	0.97	1.08	0.99
5	East	0.99	0.94	0.92	0.96	1.02	0.97
6	West Southwest	0.99	0.97	0.98	1.02	1.10	1.01
7	East Southeast	1.05	0.97	1.02	1.01	1.12	1.03
8	Southwest	1.11	1.09	1.10	1.13	1.26	1.14
9	Southeast	1.07	1.09	1.04	1.03	1.09	1.06
10	South	0.96	1.02	1.06	1.03	0.99	1.01

Confidence Intervals

Table 6 Precipitation Frequency Estimates (in inches) with 90% Confidence Intervals (continued)

Storm Code	Section Code	Recurrence interval						
		2-year	5-year	10-year	25-year	50-year	100-year	500-year
5	1	**3.34** (3.00 - 3.69)	**4.22** (3.79 - 4.68)	**5.03** (4.50 - 5.61)	**6.20** (5.51 - 6.99)	**7.20** (6.34 - 8.21)	**8.25** (7.20 - 9.54)	**10.84** (9.16 - 13.00)
5	2	**3.34** (3.00 - 3.69)	**4.30** (3.85 - 4.77)	**5.15** (4.60 - 5.73)	**6.45** (5.71 - 7.26)	**7.50** (6.59 - 8.55)	**8.57** (7.46 - 9.93)	**11.24** (9.48 - 13.63)

New format

Before…

Table 4 Storm and Sectional Codes for Table 5

Storm Code	
1	240 hours
2	120 hours
3	72 hours
4	48 hours
5	24 hours
6	18 hours
7	12 hours
8	6 hours
9	3 hours
10	2 hours
11	1 hour

Sectional Code	
1	Northwest
2	Northeast
3	West
4	Central
5	East
6	West Southwest
7	Southeast
8	Southwest
9	Southeast
10	South

Table 5 Rainfall Frequencies

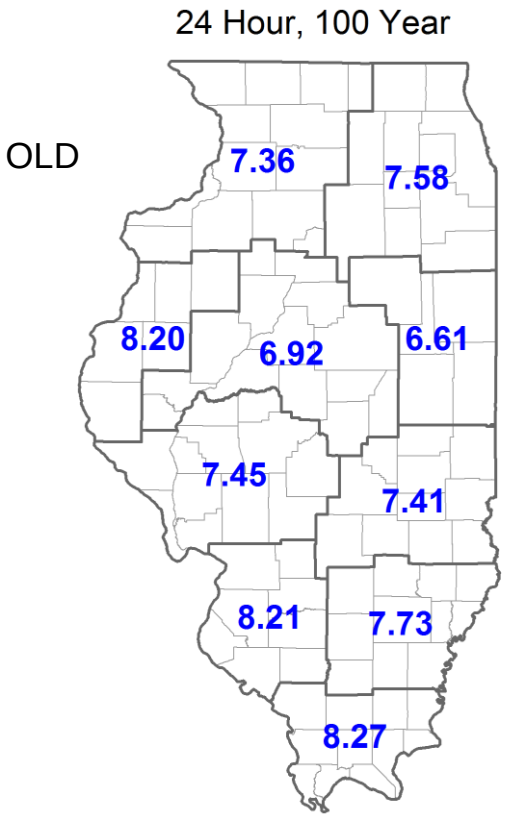
		Rainfall (inches) for given recurrence interval						
Storm code	*Section code*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*	*500-year*
1	1	5.48	6.86	7.98	9.55	10.84	12.14	15.65
1	2	5.60	7.09	8.25	9.90	11.26	12.65	16.00
1	3	5.62	7.00	8.10	9.60	10.65	11.64	13.99
1	4	5.46	6.87	8.04	9.53	10.55	11.50	13.65
1	5	5.50	6.84	7.90	9.35	10.45	11.55	13.96
1	6	6.00	7.38	8.47	9.95	10.99	11.95	14.08
1	7	6.57	7.86	8.90	10.20	11.20	12.06	13.95
1	8	6.75	8.18	9.30	10.80	11.95	13.10	15.95
1	9	7.06	8.30	9.22	10.37	11.21	11.96	13.75
1	10	6.36	7.65	8.76	10.40	11.66	12.96	16.20
2	1	4.35	5.51	6.46	7.88	8.96	10.20	13.33
2	2	4.42	5.63	6.68	8.16	9.39	10.66	13.81
2	3	4.51	5.66	6.62	7.94	8.93	9.83	11.99
2	4	4.27	5.42	6.42	7.75	8.72	9.60	11.54
2	5	4.34	5.43	6.41	7.73	8.79	9.80	11.93
2	6	4.49	5.60	6.49	7.77	8.69	9.57	11.53
2	7	5.00	6.11	7.01	8.23	9.11	9.95	11.71
2	8	5.31	6.51	7.47	8.79	9.81	10.84	13.45
2	9	5.73	6.78	7.60	8.64	9.47	10.20	11.97
2	10	5.18	6.30	7.29	8.69	9.78	10.91	13.84

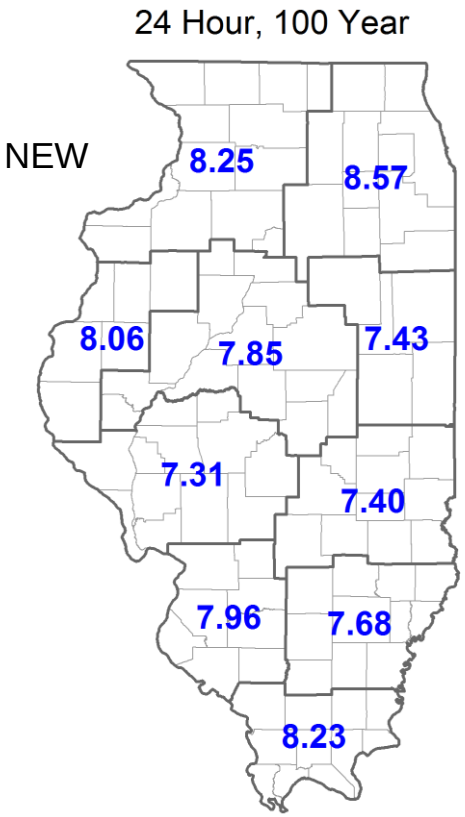
After…

Storm Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year	500-year
5 minutes	0.19	0.22	0.24	0.27	0.31	0.33	0.40	0.52	0.62	0.77	0.90	1.03	1.35
10 minutes	0.35	0.40	0.43	0.49	0.56	0.61	0.73	0.95	1.13	1.42	1.65	1.89	2.47
15 minutes	0.42	0.49	0.53	0.61	0.69	0.75	0.90	1.16	1.39	1.74	2.03	2.32	3.04
30 minutes	0.58	0.66	0.73	0.83	0.94	1.03	1.24	1.59	1.91	2.39	2.78	3.17	4.16
1 hour	0.74	0.84	0.93	1.05	1.20	1.30	1.57	2.02	2.42	3.03	3.53	4.03	5.28
2 hours	0.91	1.04	1.14	1.30	1.48	1.61	1.94	2.49	2.99	3.74	4.35	4.97	6.52
3 hours	1.00	1.15	1.26	1.44	1.63	1.77	2.14	2.75	3.30	4.13	4.80	5.49	7.20
6 hours	1.18	1.35	1.48	1.68	1.91	2.08	2.51	3.23	3.86	4.84	5.63	6.43	8.43
12 hours	1.37	1.56	1.71	1.95	2.21	2.41	2.91	3.74	4.48	5.61	6.53	7.46	9.78
18 hours	1.48	1.69	1.85	2.11	2.39	2.61	3.14	4.04	4.84	6.06	7.05	8.06	10.57
1 day	1.57	1.80	1.97	2.24	2.55	2.77	3.34	4.30	5.15	6.45	7.50	8.57	11.24
2 days	1.72	1.97	2.16	2.46	2.79	3.04	3.66	4.71	5.62	6.99	8.13	9.28	12.10
3 days	1.87	2.14	2.34	2.67	3.03	3.30	3.97	5.08	6.05	7.49	8.64	9.85	12.81
5 days	2.08	2.38	2.61	2.97	3.37	3.67	4.42	5.63	6.68	8.16	9.39	10.66	13.81
10 days	2.63	3.01	3.30	3.76	4.27	4.65	5.60	7.09	8.25	9.90	11.26	12.65	16.00

Table 5.4. Rainfall (inches) for given recurrence interval for Section 2 (Northeast)

Bulletin 70 and Bulletin 75
100-Yr, 24-Hour Storm





Bulletin 75 vs Bulletin 70
Differences in inches

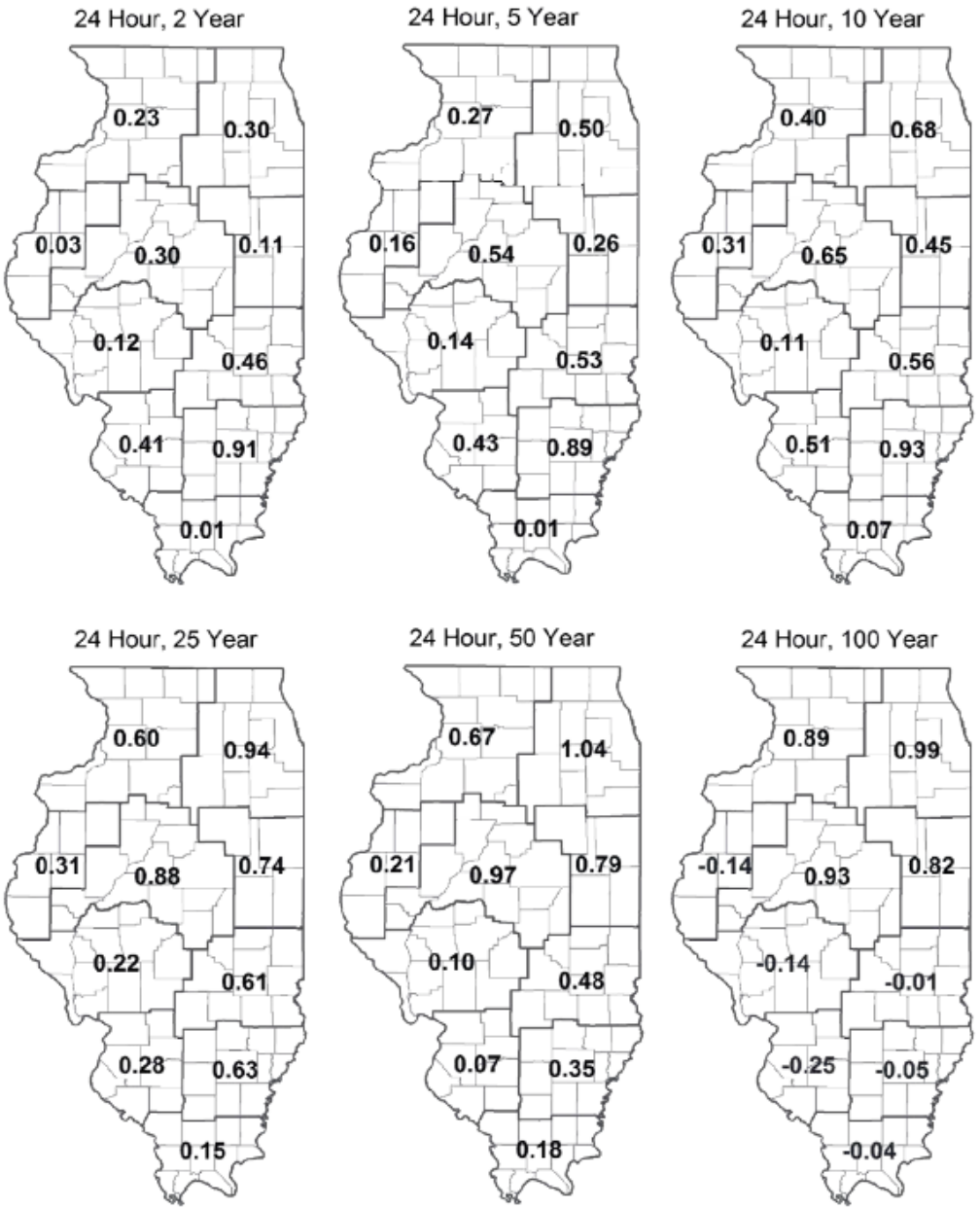


Figure 19 Differences in inches between this study and Bulletin 70 for a 24-hour duration and 2-, 5-, 10-, 25-, 50-, and 100-year frequencies for 10 sections in Illinois. Positive numbers denote an increase and negative numbers show a decrease compared with Bulletin 70.

Bulletin 75 vs NOAA Atlas 14
Differences in inches

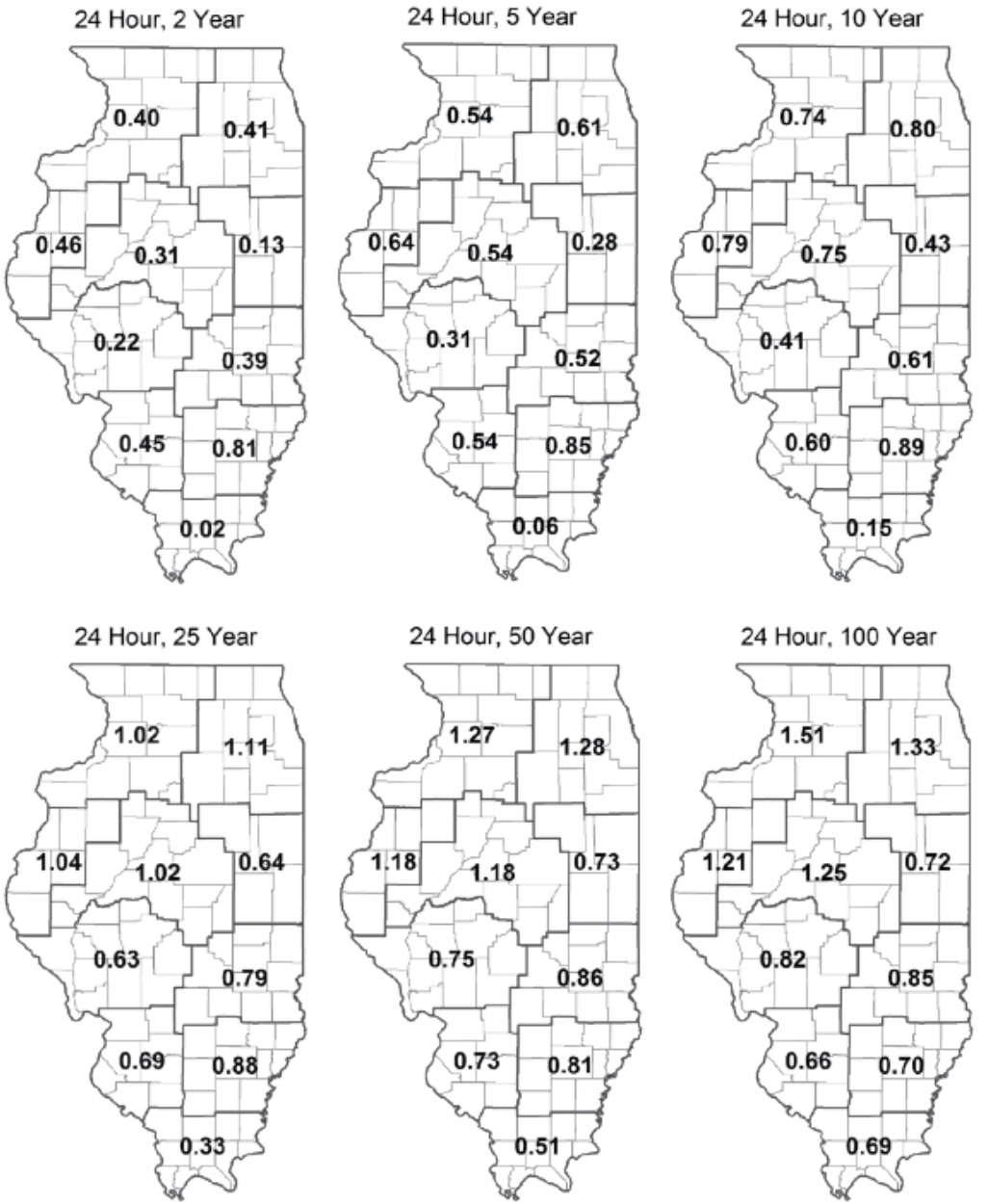


Figure 29 Differences in inches between this study and NOAA Atlas 14 for a 24-hour duration and 2-, 5-, 10-, 25-, 50-, and 100-year frequencies for 10 sections in Illinois. Positive numbers denote an increase and negative numbers show a decrease compared with Atlas 14.

Final thoughts on Bulletin 75

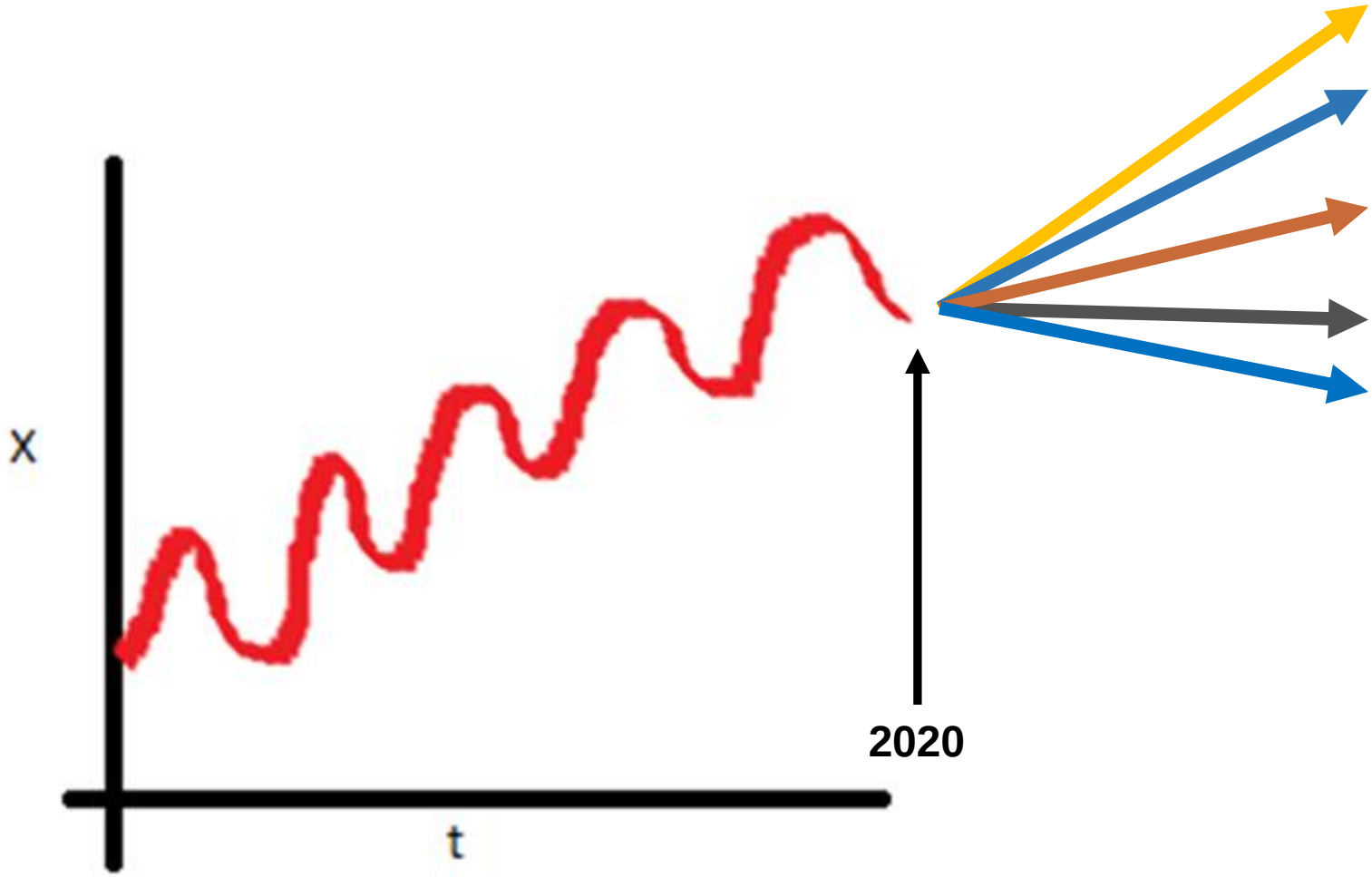
- Frequency estimates in Bulletin 75 represent the present time.
- Climate studies indicate that the trends will continue in the future. As a result of the increasing rainfall, the structures designed based on Bulletin 75 may not be adequate for future (e.g. 2050) rainfall magnitudes.
- Thus, similar studies using the projected climate modeling data need to be performed to determine future rainfall frequencies.


Questions/comments?

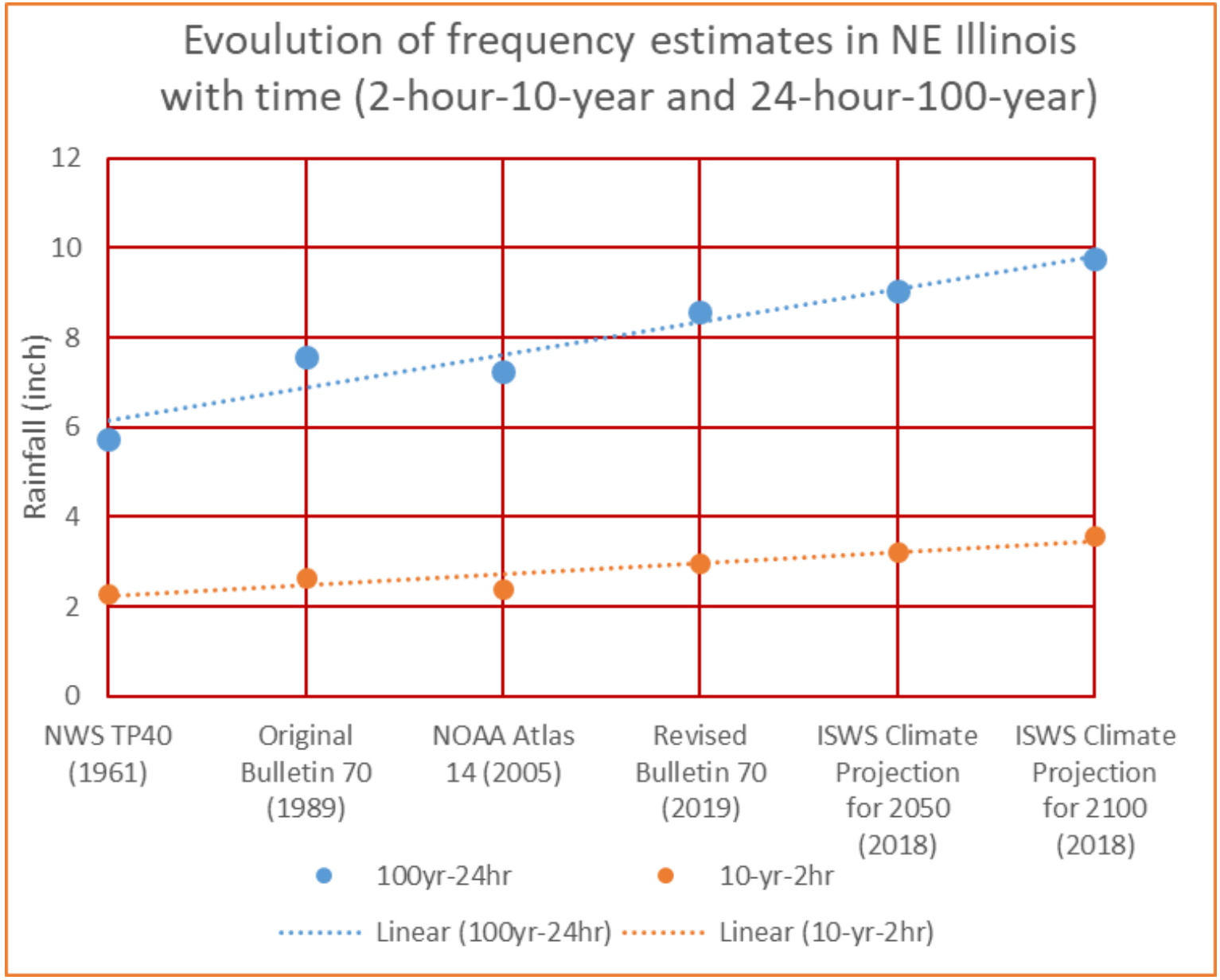
- Volume I of the NCA4
- Precipitation will continue to increase (medium confidence)
- Heavy precipitation events will increase in frequency and amounts (high confidence)

https://science2017.globalchange.gov/

Nonstationarity of heavy rainfall



Non-Stationary series


Evoulution of frequency estimates in NE Illinois with time (2-hour-10-year and 24-hour-100-year)
Rainfall (inch)
0
2
4
6
8
10
12
NWS TP40 (1961)
Original Bulletin 70 (1989)
NOAA Atlas 14 (2005)
Revised Bulletin 70 (2019)
ISWS Climate Projection for 2050 (2018)
ISWS Climate Projection for 2100 (2018)
100yr-24hr
10-yr-2hr
Linear (100yr-24hr)
Linear (10-yr-2hr)

Future change (%)
Northeastern United States
RCP8.5